

2.11 On all high priority circuits of any type where continuity of service is important and only the minimum outage time can be tolerated (such as fire alarm circuits, interoffice or EAS trunk circuits, and data circuits.)

2.12 On all carrier circuits where lightning incidence is significant.

2.13 For all subscriber station protectors in areas with a record of high station protection maintenance costs with carbon blocks or plant or equipment damage due to lightning surges or power fault current induced surges.

2.14 For all mainframe protectors in unattended central offices located in areas with a record of high protector maintenance or equipment failures caused by lightning or power fault current induced surges.

2.2 Four basic factors should be considered in determining the general areas in which to use gas tube protection. They are: (1) Earth resistivity, (2) lightning incidence (3) long exposures to power systems with high fault currents, (See TE & CM Section 825 App. "A") and (4) the maintenance costs of replacing a grounded protector. The reasons for their consideration are as follows:

2.21 As earth resistivity increases, the area of earth potential rise created by lightning stroke also increases. Thus, cables within a given distance of the ground termination of a lightning stroke will be exposed to higher voltages in areas of greater earth resistivity than of low, and the probability that the stroke will arc to the cable is increased correspondingly.

2.22 As the frequency of thunderstorms, and hence of lightning strokes, increases the probability that a given facility will be struck during a given time period becomes greater. (e.g., Plant in an area with 100 thunderstorm days per year would be ten times more likely to receive a damaging stroke in a given time period than one in a ten thunderstorm days per year area if all other variables were the same.)

2.23 The greatest amount of lightning damage to telephone plant and equipment occurs in areas which have a combination of generally high earth resistivity (greater than 500 meter-ohms or 50,000 ohm-centimeters) and high lightning incidence (greater than 50 lightning storm days per year.) The shaded portions of the map on Figure 1, "Lightning Damage Probability Map" indicate areas where greater than average damage can be expected. See TE & CM-801 for a more detailed discussion.

2.24 While Figures 1 and 2 indicate geographical areas where telephone systems probably experience protection problems due to the above, the duty to which an arrester is subjected will vary widely within a small geographic area; e.g., one circuit route confined to a valley with tall trees for shielding may require minimal protection while another route less than a mile away may require extensive protection because it serves an exposed hilltop location.

Protection experience gained from circuits serving similar locations within the area should be taken into account when considering the application of gas tube protection.

2.25 Power fault current problems are generally associated with telephone plant located in close proximity and long parallels to power circuits with high fault currents. The incidence of the faults on power systems are generally related to the incidence and severity of lightning. The anticipated number of lightning strikes in a given area is a function of the number of thunderstorms anticipated during the thunderstorm season. Figure 2, "Mean Number of Days with Thunderstorms, Annual" provides a guide to this consideration.

2.26 In considering gas tube applications for induced surges from power fault currents, some plant routes either aerial or buried, will be exposed to paralleling power lines while others will not. Power contacts will be a factor only where aerial cable or open wire is used and where they are involved in joint use with or built in close proximity to power lines or are exposed via line crossings. Again, experience in each specific area and for each plant route or, if experience is lacking, sound engineering judgement, should determine the need and benefits that can be derived from the use of gas tubes. (Calculations, as described in Appendix A to TE & CM-825, will be of value in formulating engineering judgements.)

2.27 With maintenance and related labor costs soaring, eliminating long, time consuming trips to replace grounded protectors is a sound investment. Thus remote stations in even moderate lightning areas should be equipped with gas tubes.

3. GAS TUBE ARRESTER CHARACTERISTICS AND SURGE AND ARRESTER NOMENCLATURE

3.1 Basic Types of Gas Tubes: At the present time there are two basic types of gas tubes listed by REA. They are "Two Electrode" and "Three Electrode" types. Two electrode tubes are applied as totally separate and independent gaps between each side of the pair and ground. The devices operate independently of each other whenever the voltage to ground exceeds the breakdown rating of the gaps. Thus, the tip side of a pair could breakdown and effectively short the tip side to ground. The ring side gap would not necessarily have broken down. This then could create a voltage difference between the tip and ring conductors, which could be fairly large. If this voltage is sufficient to breakdown the ring conductor gap, it in turn will short the ring side to ground. The three element tubes have three electrodes in the same gas chamber. One for each side of the pair and one for ground. In theory, when the voltage to ground on either side exceeds the breakdown voltages of the tube, the tube breaks down and the resulting ionization of the gas shorts both sides of the line to ground nearly simultaneously. With such tubes, the voltage between the tip and ring (transverse voltage) should generally be held to very low values.

3.2 Surge Characteristics

3.21 A typical lightning surge is illustrated in Figure 3. The surge tends to be nonlinear in the early portion of its rise and also as the crest is reached. As a result, the rate of rise is defined as the slope of the curve from 10 percent of its voltage or current amplitude (A) to 90 percent A. For example, assume a surge with a crest voltage of 2,000 volts requires three microseconds for the voltage to build to 200 volts, another four microseconds to reach 1800 volts, and three additional microseconds to reach 2000 volts. Using the crest voltage, the total time to reach crest, the result is a rate of rise 2000 volts divided by 10 microseconds, or $200\text{V}/\mu\text{s}$. This is not typical of the major portion of the wave's rise. The 10 to 90 percent portion of the rise time takes four microseconds to rise 1600 volts; thus the rate of rise as defined by REA would be $400\text{V}/\mu\text{s}$ during this "typical" time. This latter is the figure usually given as "Rate of Rise" by manufacturers.

3.211 The typical surge decays exponentially after the crest voltage or current is reached. The standard industry practice is to describe this rate of decay by giving the time from initiation of the surge until the surge has decayed to $1/2$ its crest value. Other methods, such as specifying the time from crest to $1/2$ value, are used by some. In the interest of clarity and standardization we recommend use of the terms in Figure 3.

3.212 A surge is described by the crest voltage or current, followed by its wave shape, first the rise time then the time to decay to $1/2$ value: e.g., 500 volts $5/1000$ microseconds as illustrated in Figure 3.

3.22 Figure 4: "Arrester Breakdown Nomenclature"---shows a plot of voltage versus time for an arrester operation.

3.221 Most arresters breakdown, and ground the circuit at a higher voltage when subjected to a surge than when subjected to slowly rising dc voltage. As a result, both surge and dc breakdown voltages are important. As surge breakdown voltage is a function of surge rate of rise, a surge breakdown voltage should not be specified unless the rate of rise is also given; e.g., a surge breakdown voltage of 1000 volts on a $500\text{V}/\text{microsecond}$ rise.

3.2221 Breakdown: Defined as that point at which the arrester changes from a nonconducting to a conducting condition, where current is discharged through the arrester and the voltage drop across the arrester does not exceed 50 volts. (NOTE: Breakdown should not be confused with failure.)

3.2222 Breakdown Delay Time: REA defines this as the time that equipment protected by an arrester will be subjected to voltages in excess of the dc breakdown voltage of the arrester, e.g., a device protected by a 350V arrester may be subjected to rising voltages (above the dc breakdown) of up to perhaps 1200V or more for two to three microseconds on a $500\text{V}/\text{microsecond}$ rise. While the time is small, the excessive voltage may damage the equipment. (NOTE: Electronic equipment generally contains secondary lower voltage protection, such

as zener diodes plus resistors, which can withstand substantial voltage and current surges for a few microseconds.)

3.2223 Transition Time: The time required from the initiation of breakdown until the voltage drop across the tube becomes less than 50 volts. The sum of transition time and rise time from dc breakdown voltage to surge breakdown voltage represents the period during which a circuit will be subjected to greater than the normal dc breakdown voltages. Normally, the transition time should be less than one microsecond, however, the voltages encountered for this period may be substantially above the tubes rated dc breakdown.

3.3 "Fail Safe" Operation of Arresters: The term "fail-safe" operation of arresters has many different meanings within the industry. To the telephone protection engineer, "fail-safe" operation means that the arrester will protect the equipment and/or personnel under virtually all overload and environmental conditions to which it may be subjected during its service life, and continue to provide protection after the arrester is no longer capable of clearing, or restoring the circuit to normal operation after a surge. From practical considerations this means that arrester failures must always be in the short circuited mode or low breakdown mode.

3.31 Present designs of gas tube arresters are inherently not 100% "fail-safe" by the above definition because their breakdown characteristics depend on the presence of a particular gas and pressure, which in turn depend on an intact seal of the enclosing tube. Loss of the seal usually results in a large increase in breakdown voltage so that effective protection is lost and no indication of the loss is transmitted to maintenance personnel. Accordingly, the term "Fail-Safe" as defined above can not be applied to "gas tubes" of present designs.

3.32 Air-gap carbon arresters of modern design do not depend on gas tight seals for their breakdown characteristics and normally fail in the short circuited mode if subjected to abnormally high currents or frequent breakdown. Accordingly, the term "Fail-Safe" can be applied to carbon block protectors.

3.33 Because of the various aspects of "fail-safe", REA uses the term only when its meaning is restricted to the definition given in Paragraph 3.3. For gas tube surge arresters, REA will be using the following terms:

3.331 "Short circuit or low breakdown failure mode." Tubes having this failure mode should always fail from effects of operations by a decrease in breakdown voltage (to the point where normal line voltage causes the tube to fire, thus signalling a problem) or by a low resistance path which grounds the circuit. These units when mechanically intact should never fail by a significant increase in breakdown voltage. Gas tube types of station protectors listed by REA are required to comply with failure in the short circuit or low voltage mode.

3.332 "High breakdown voltage failure mode." Tubes having this failure mode should always fail as a result of operating duty by significant increase in breakdown voltage. Tubes with only this failure mode should never be used where personal shock hazard is a consideration. Some main frames protectors and field mounted electronic equipment protectors may utilize tubes with this failure mode.

3.333 Since there are variations in the industry as to the meaning of "fail-safe" operation, it is essential that borrowers and engineers determine precisely what is meant by the term when used by others.

3.34 While gas tubes have been designed to minimize the possibility of seal breakage, consideration should be given to sample testing of gas tubes in telephone plant periodically to determine breakdown characteristics. Where the samples tested indicate a high percentage of failure, the testing should be increased to include other protectors with the same general exposure. The time interval at which tubes should be sample tested will vary depending on a number of factors. They include:

3.341 Severity of lightning problems in the area. Tubes on a carrier route in North Dakota (a less than average problem area,) should for example require less sampling than those protecting an identical route in Georgia.

3.342 Importance of protector remaining operational. Tubes in station protectors (when human shock is a potential hazard) or on fire alerting circuits, should receive more frequent attention than single field mounted VF repeaters for example.

3.343 Classification of tube employed. REA rates tubes as light, standard, or heavy duty depending on energy handling ability and life. The light duty tube should be expected to fail much earlier than the heavy duty tubes when exposed to the same number of strikes.

3.344 Occurrence of power system faults. If tubes are exposed to severe power system faults, either by induction or conduction as indicated by damage to plant, consideration should be given to sample testing along the route where the fault or faults occurred.

3.345 Gas tube test equipment for testing dc breakdown is available from several manufacturers. These devices are intended primarily to locate tubes which have failed in the high breakdown, low breakdown, or short circuited mode.

3.4 Arrester Breakdown: When selecting an arrester, the dc breakdown and breakdowns on surges rising at 500 and 10,000 volts per microsecond are usually of interest.

3.41 DC Breakdown is of concern because if it is too low, the arrester may breakdown at a lower voltage than used to power the circuit associated with the arrester; e.g., an arrester breaking down at 90V would be a poor selection for a carrier circuit with a 130V dc power supply, or a voice frequency line employing 96V boosted battery and 155V rms ringing.

3.42 Surge break down voltage is of interest because the arrester will not provide the required protection if its surge breakdown voltage is too high. The characteristics of surges induced in telephone plant vary widely. Rates of rise may be as slow as several volts per millisecond, or as rapid as many thousands of volts per microsecond. In general, the voltage at which an arrester will break down becomes greater as surge rate of rise increases. This is not, however, a simple linear relationship. In addition, the higher capacitance of cable plant tends to slow the surge rate of rise and increase the decay time greatly compared to open wire plant. As a result, REA requests surge breakdown data on only two rates of rise: 500V per microsecond and 10KV per microsecond. A study of the available information indicates that the former is typical of surges in cable while 10KV/microsecond is appropriate for open wire.

3.5 Single Surge Capability: This parameter is a measure of the largest single current surge an arrester can be expected to survive without significant damage. In order to obtain an objective comparison between several arresters, the surge test waveshape must be the same for all samples. The fallacy of comparing single surge capability on different wave shapes is illustrated by the following example:

3.51 The energy delivered to the arrester is approximately proportional to the product of $I^2 \times T$. The energy in a 10KA 10/50 wave is shown by the cross-hatched area in Figure 5, while Figure 6 illustrates that in a 10KA 10/20 wave. From these figures, it becomes readily apparent that an arrester rated at 10KA on a 10/50 wave will handle much more energy than one rated similarly on a 10/20 wave.

3.6 DC Holdover: When an arrester is on a line which has dc impressed on it, and is subjected to a surge, there is a tendency for the dc to force the arrester to remain in the low impedance, or short circuited state after the surge has passed to ground. The dc holdover voltage is defined as the maximum level of dc under which an arrester may be expected to clear and restore the circuit to normal operation after being subjected to a breakdown while dc voltage is standing on the line. Holdover is a function of both voltage across the arrester and available current. As a result, REA recommends that carrier suppliers design power feeds that limit or remove current when nearby gas tubes operate. REA recommends a rather complex circuit and a series of waveshapes for testing this characteristic. These arrangements are discussed in PE-55. Holdover capability of a tube should always exceed the maximum steady state dc applied on the circuit being protected. For example, a tube with dc holdover of 90V would be a poor choice for a circuit employing a loop extender which is powered by 110V.

3.61 Special consideration should be given to dc holdover when using three electrode gas tubes with some carrier systems. As the two electrodes connected to tip and ring share a common gas chamber, there is a possibility of dc holdover from line to line when the carrier power is applied as a positive voltage from one line to ground and a negative voltage from the other line to ground. For example, a three electrode gas tube used with a carrier system powered by ± 125 volts line to ground would be required to withstand 250 volts from line to line, unless special circuitry is incorporated in the power feed to limit the current available under breakdown conditions.

3.7 Surge Life: While some gas tubes have excellent single surge capability, experience has shown they can be made to fail by repeated applications of lesser surges. As the primary reason for using gas tubes in place of carbon is to obtain an increased service life, the number of surges an arrester can survive without failure is very important. In order to obtain an objective comparison between several arresters, the surge test waveshape must be the same for all samples. REA has selected the 500 amperes 10/1000 microsecond and 10KA 10/50 microsecond waves. NOTE: When checking surge life, the mode of failure (arrester shorted, or arrester strike voltage increased beyond tolerance) is very important. (See the discussion of "Fail-Safe" in Paragraph 3.3.)

3.8 60HZ Current Carrying Ability: An arrester may be subjected to 60HZ either through direct contact, when a power line falls on aerial cable or open wire, or through induction in the case of a phase-to-phase power fault or a phase-to-ground fault on a near by power system that does not contact the telephone plant. As a result, the 60HZ current carrying ability of an arrester is of interest. A typical power circuit breaker requires up to about 11 cycles (0.18 second) maximum to trip. Therefore, data furnished by manufacturers of the gas tube on characteristics should cover tests made for this duration time.

3.9 First Time Effect: Recent field experience has shown that some gas tubes exhibit "First Time Effect". That is, when placed in a darkened environment for two weeks or more without being energized, the tubes may demonstrate an initial breakdown well in excess of their rated breakdown (e.g., a tube rated at 350V, dc, normally breaks down about 750V on a 500V/ μ s surge. Due to First Time Effect this tube may not breakdown until 2100V on the first surge after a inactive period.) Subsequent breakdowns, unless the extended unenergized storage period is repeated, should be normal. The initial elevated breakdown may be sufficient to permit electronic equipment to be damaged. Tubes meeting REA specifications are free from this characteristic.

3.10 Physical Construction: The ability of a gas tube arrester to retain its gas is of primary importance if it is to serve its function as an arrester. As a result, the physical construction of the tube should be considered carefully when specifying a gas tube arrester for specific applications. In general, tubes of metal and ceramic construction will prove more rugged than those primarily of metal and glass.

4. SELECTION OF AN ARRESTER

4.1 The best arrester for any given application can be determined by considering the major characteristic of the available arrester (Paragraph 3) and the characteristics of the equipment that is to be protected as well as the economics of the situation.

4.11 The provision for adequate electrical protection for special electrical equipment such as carrier, VF repeaters etc., used in telephone systems is the responsibility of the equipment supplier. Usually this involves specifically designed combinations of zener diodes and resistors to provide low voltage protection for solid state circuitry, coordinated with the surge breakdown characteristics of gas tube or carbon block arresters. In some cases, the user has the option of specifying gas tubes or carbon blocks that are supplied with the equipment.

4.12 It is the responsibility of the telephone company to provide adequate subscriber station protectors. If a decision, based on information contained in Paragraph 2, has been made to replace carbon protectors with gas tube protectors, there are overriding human and subscriber property safety considerations that should be given careful thought. If replacement of the complete protector is involved, the replacement should be one of those listed on page "ni" of the "List of Materials Acceptable for Use on Telephone Systems of REA Borrowers." To have such a listing the protector must meet all applicable requirements of REA Specifications PE-42 and PE-55 or PE-56. If replacement of only the arrester unit is contemplated the resulting combination of arrester units and mounting should be listed by UL and meet all applicable requirements of REA Specifications mentioned above.

4.121 In order for a gas tube to be listed for use in station protectors, it must meet the requirements of a standard or heavy duty tube as set forth in PE-55 and PE-56. Station protectors employing both classifications are available, and their listing in REA's "List of Materials" designates which classification each meets. In general, heavy duty protectors are more expensive than standard duty units, however, their energy handling ability and life expectancy are also greater. Thus, in situations where power crosses, induction, or lightning strokes are unusually heavy, the use of heavy duty tubes should be considered. Engineering judgement will be required in making the decision between standard and heavy duty tubes, depending on the anticipated exposure.

4.13 In the case of a cable carrier system, outage time becomes the prime consideration. Breakdown voltage on a surge rising at a rate of 500V/ μ s simulating lightning in cable, as discussed in Paragraph 3.2, is of concern. DC holdover is another characteristic of concern with carrier because some systems are powered from the central office by dc in excess of ± 130 volts to ground. With cable carrier, generally the chance of a 60Hz power contact is small, so tubes without a high 60Hz current carrying ability could be used.

4.14 In the case of an open wire line serving a critical Forest Service fire tower, high atop a rocky ridge, where outage time must be held to the

minimum, breakdown voltage at 10KA/ μ s would be very important, as explained in Paragraph 3.22. Also, greater energy handling ability would be desirable and, as there is a risk of 60Hz power contact, a heavy duty tube with good 60Hz current carrying ability should be chosen.

4.15 In the case of a microwave installation on top of a hill, the overriding consideration would be assuring minimum channel outage. The location of the facility is such that it would probably receive many more than the average number of severe lightning strokes. Microwave systems usually carry a large number of circuits which should be protected where the circuits are terminated at carrier or voice frequencies. Under these conditions the cost of the arresters is a very minor consideration. The arrester having the greatest ability to withstand very large and repeated surges without becoming permanently grounded, or without being physically damaged should be used.

4.16 In the case of the mainframe in an unattended central office serving a high lightning area through primarily buried plant, with no potential power fault problems, it might be possible to use light duty gas tubes, and save money on the installation while gaining the advantage of gas protection. Conversely, if severe surges are reaching the office, standard or heavy duty tubes may be justified.

4.17 In choosing whether the three element or two element types of gas tubes should be utilized, the nature and extent of exposure to lightning or power surges and the vulnerability of the equipment should be considered carefully. If the equipment protected is not particularly sensitive to transverse voltages then either type of tube could be used. The selection should then be made on the basis of total relative costs of the protection systems. On the other hand, transverse voltage sensitivity would favor the selection of the three element type.

4.18 The above are but a few examples in the process of selecting the proper gas tube for a given task. To provide examples of all cases in which gas tubes might be used and guidelines for tube selection would be impractical. As a result, the above examples have been included to illustrate the methods' and lines of reasoning employed.

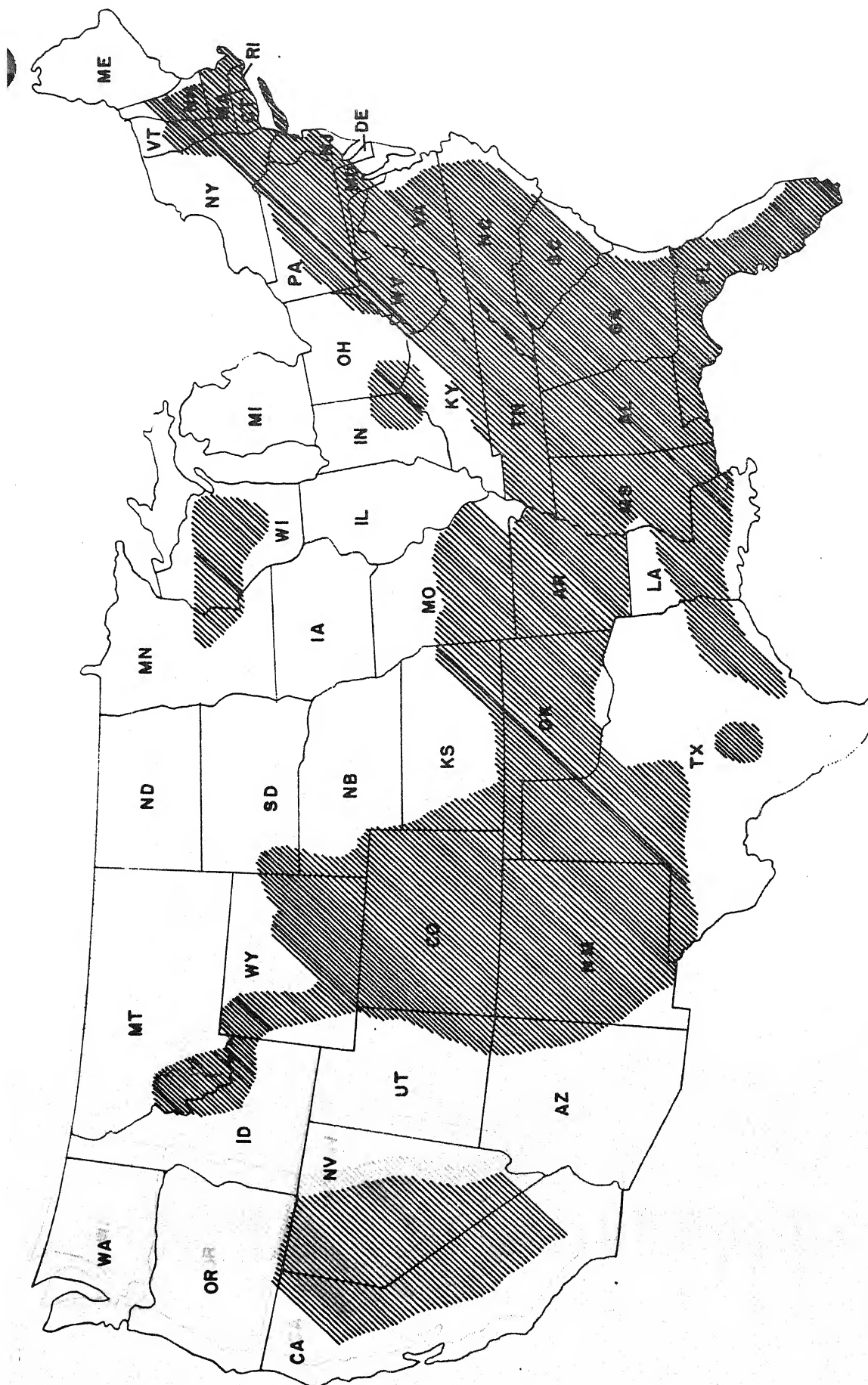
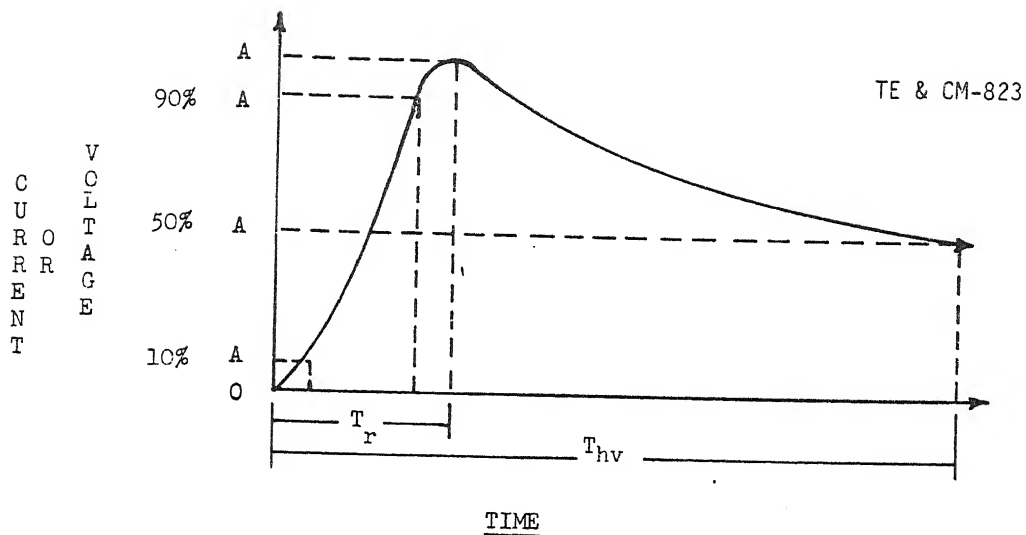


Fig. 1- LIGHTNING DAMAGE PROBABILITY MAP-SHADED AREAS INDICATE A GREATER
THAN AVERAGE PROBABILITY OF LIGHTNING DAMAGE

FIG. 2--MEAN NUMBER OF DAYS WITH THUNDERSTORMS, ANNUAL





A Maximum, or crest, current or voltage
 Tr Rise Time
 Thv Time to 1/2 crest value (Decay Time)
 Rate of Rise Slope of the curve from 10%A to 90%A
 Surge Waveshape is specified as follows: A, Tr/ Thv
 e.g.: 500 volts, 5/1000 Microseconds

FIGURE 3: SURGE WAVESHAPE NOMENCLATURE

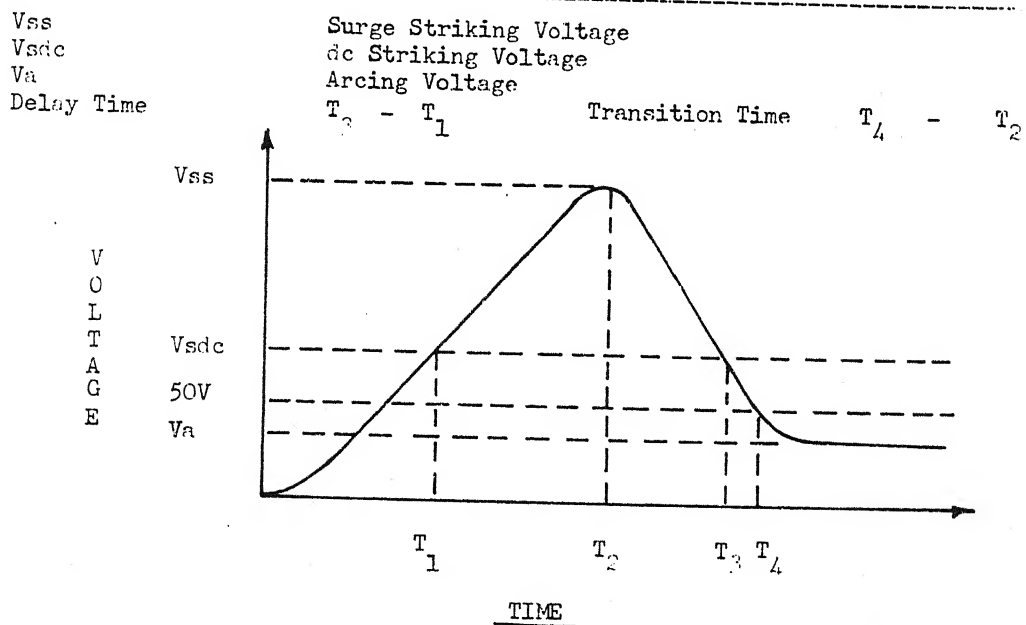


FIGURE 4: ARRESTER BREAKDOWN NOMENCLATURE

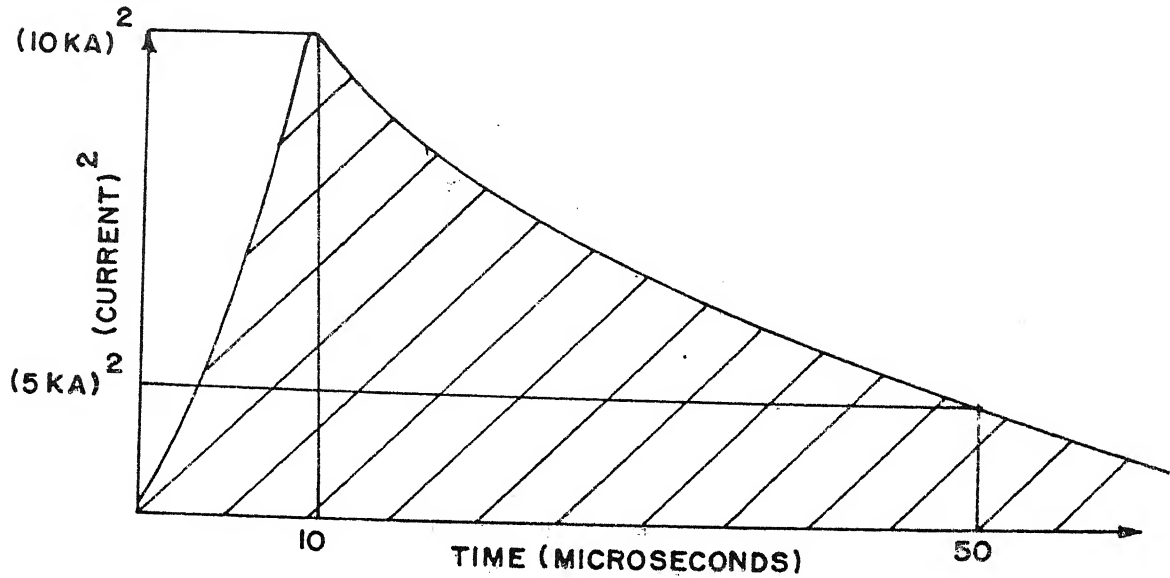


FIGURE 5: ENERGY IN A 10kA 10/50 WAVE

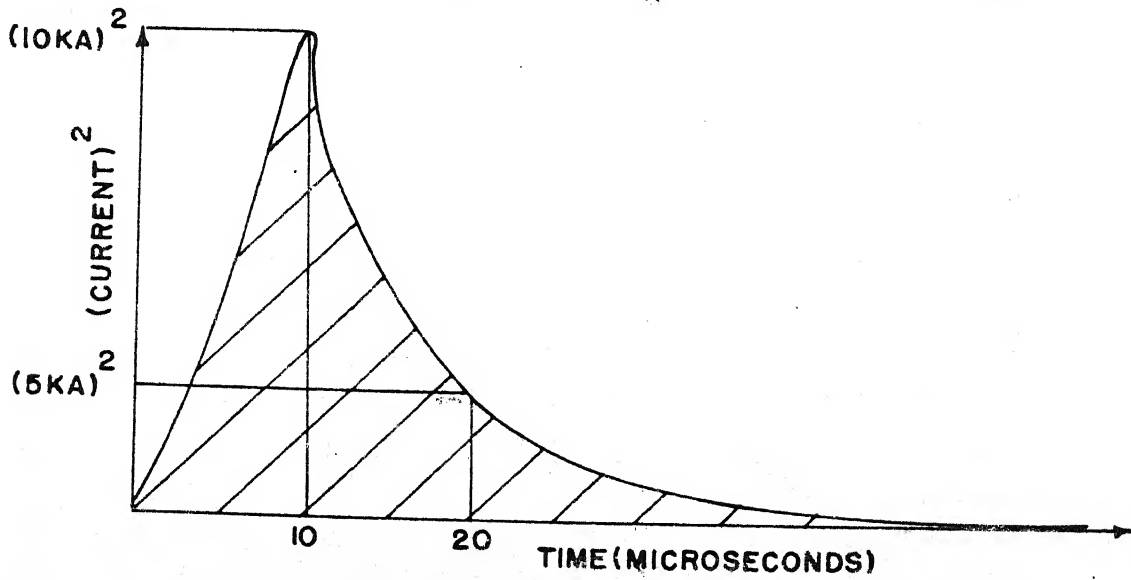


FIGURE 6: ENERGY IN A 10kA 10/20 WAVE